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Investing in nature: Developing ecosystem service markets for peatland restoration

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ABSTRACT

To meet the challenge of proactive ecosystem-based climate mitigation and adaptation, new sources of funding are needed. Peatlands provide the most efficient global store of terrestrial carbon. Degraded peatlands, however, contribute disproportionally to global greenhouse gas (GHG) emissions, with approximately 25% of all CO_2 emissions from the land use sector, while restoration can be cost-effective. Peatland restoration therefore provides a newopportunity for investing in ecosystem-based mitigation through the development of carbon markets. Set in the international policy and carbon market context, this paper demonstrates the necessary scientific evidence and policy frameworks needed to develop ecosystem service markets for peatland restoration. Using the UK and NE Germany as case studies, we outline the climate change mitigation potential of peatlands and how changes in GHG emissions after restoration may be measured. We report on market demand research in carbon market investments that provide sponsors with quantification and officially certified recognition of the climate and other co-benefits. Building on this, we develop the necessary requirements for developing regional carbon markets to fund peatland restoration. While this paper focuses on the UK and German context, it draws on international experience, and is likely to be directly applicable across peatlands in Europe and North America.

1. Introduction

Peatlands have been identified as a priority for action under international agreements. Global agreements such as the UN Convention on Biological Diversity (CBD) and its Nagoya protocol, the UNFCC and its Kyoto Protocol as well as the Ramsar Convention on Wetlands promote peatland restoration as a key contribution towards reaching biodiversity and climate targets (Bonn et al., in press; Joosten, 2011; IPCC, 2014). At the same time a range of national and regional activities are forming to develop payment for ecosystem service schemes (Sattler and Matzdorf, 2013) for peatland restoration through agri-environment schemes (Reed et al., 2014) and compliance and voluntary markets. In this paper, we analyse lessons learned from developing carbon markets, using case studies in the UK and NE Germany.

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Intact peatlands provide many important ecosystem services, including climate regulation through carbon sequestration and storage, water regulation, provision of palaeo-environmental archives and recreation opportunities, as well as provision of habitats for nationally and internationally important wildlife (Bonn et al., in press). When drained, however (typically to increase provisioning services such as agriculture and forestry), peatlands can turn into significant sources of greenhouse gas (GHG) emissions and affect water quality, human health and biodiversity (Bonn et al., 2009b; Parish et al., 2008; van der Wal et al., 2011). Drained organic soils with low water tables continue to degrade and to emit CO_2, until either drainage is reversed or all peat is lost. Degraded peatlands are responsible globally for 25% of CO_2 emissions from the land use sector, and in the European Union for 75% of GHG emissions from agricultural land use (Joosten, 2009). Degraded peatlands pose a high risk and, ultimately, high costs to society.

Given growing national and global political recognition of the climate mitigation benefits of conserving and restoring peatlands that reinforce their established biodiversity value (Littlewood et al., 2010), opportunities to fund these activities have greatly increased. To achieve restoration at the regional country scale or to reverse peatland degradation at a global scale, a combination of public and private investment is likely to be needed. Although the Kyoto Protocol created an international market for carbon under the UN Framework Convention on Climate Change (known as the “compliance market”, see below and Tables 2 and 3), it would require legislative changes at EU and country level for these markets to be used to support peatland restoration in Europe. Voluntary carbon markets are now trading peatland carbon, but this market has been limited by a low voluntary carbon price, combined with high verification and accreditation costs (Kossoy and Guigon, 2012). Although the Corporate Social Responsibility market may be more likely to cover restoration costs due to higher investment potential, this is a much smaller market. There is therefore growing interest in the creation of regional carbon markets, selling the climate benefits of restoration to buyers within the same region or country, allowing more identification of buyers with the associated projects and lowering verification and accreditation costs while adapting schemes more effectively to local conditions, as explained using the case studies in this paper.

In this article, we discuss lessons from developing ecosystem services markets for peatland restoration in the UK and NE Germany that may underpin the development of regional carbon markets elsewhere to fund peatland restoration. The paper outlines the steps that are required to create a code that provides investors with confidence that emission reductions are fully verified, transparent, additional and permanent. While peatland restoration projects may be marketed primarily on the basis of carbon and hence climate regulation, there must be safeguards to prevent trade-offs with other important ecosystem services. Standards and technical guidance within the proposed code can also consider how co-benefits, such as watershed protection, conservation of biodiversity and social goals, can be attained and potentially monetised, to help meet the costs of restoring more heavily degraded or remote sites.

2. The role of peatland restoration in climate regulation

2.1. Carbon budget of peatland ecosystems

The carbon budget of peatland ecosystems and associated GHG emissions and removals are largely controlled by the degree of water saturation, climate and nutrient status (Billett et al., 2010, IPCC, 2006; 2014).In peatlands waterlogging leads to anoxic (oxygen-poor) soil conditions, which significantly slow decomposition of dead plant material, resulting in the accumulation of peat (Clymo, 1984). In this way, peatlands have withdrawn vast amounts of carbon from the atmosphere over the past millennia, making them the most space-efficient carbon store in the terrestrial biosphere (Joosten et al., 2013b).

The carbon stored in peatlands is highly sensitive to disturbance. In particular, lowered water tables can, by increasing the

Table 1
Emission factors for intact, drained, degraded and re-wetted temperate zone peatlands (all fluxes expressed as t CO_2-eq ha^{-1} yr^{-1}).

Land class	Source	CO_2	CH_4	N_2O	GHG
Drained/degraded sites					
Cropland	IPCC Tier 1	30.10	1.46	2.47	34.02
Grassland on fen (deep-drained)	IPCC Tier 1	23.50	1.84	1.56	26.89
Grassland on fen (shallow drained)	IPCC Tier 1	14.34	1.59	0.30	16.23
Grassland on bog	IPCC Tier 1	20.57	0.70	0.82	22.09
Drained blanket bog	Peatland code	3.94	0.70	0.00	4.64
Eroded blanket bog	Peatland code	32.14	0.70	0.00	31.00
Intact/rewetted sites					
Intact blanket bog	Peatland code	−2.12	1.73	0.00	−0.40
Re-wetted bog	IPCC Tier 1	0.04	1.73	0.00	1.76
Re-wetted fen	IPCC Tier 1	2.71	4.05	0.00	6.76
Changes in GHG flux (ΔGHG)following peat rewetting					**ΔGHG**
Cropland to re-wetted fen					−27.26
Grassland on fen (deep-drained) to re-wetted fen					−20.13
Grassland on bog to re-wetted bog					−20.33
Drained blanket bog to intact blanket bog					−5.03
Eroding blanket bog to intact blanket bog					−31.40

Emission factors for CO_2, CH_4 and N_2O, and the resulting net GHG balance (based on 100 year global warming potentials of 25 for CH_4 and 298 for N_2O) were derived for an illustrative set of peatland type/land-use combinations from the IPCC Wetland Supplement (IPCC, 2014), taking data for temperate peatland systems. Positive values indicate a net emission, and negative values a net removal of greenhouse gases. Tier 1 emission factors for drained sites were taken from Chapter 2 and for re-wetted sites from Chapter 3. In all cases, the CO_2 flux incorporates ‘off-site’ emissions of CO_2 associated with DOC losses, and for drained peatlands the CH_4 emission incorporates ditch emissions, according to the IPCC methods. Indicative values for the proportion of drained peatlands occupied by ditches were taken from Table 2.4 of IPCC (2014). For blanket bogs, ‘Tier 2’ emission factors for CO_2 were obtained from an initial analysis of literature data undertaken for the UK Peatland Code by Birnie and Smyth (2013) for intact, drained and eroded bogs (note that these values are currently being updated for the next phase of Peatland Code development). IPCC methods and default values were used to add emissions from DOC and CH_4 to each category, while N_2O emissions from blanket bogs were considered to be zero. Changes in GHG emissions following re-wetting were calculated as the difference in estimated emissions between the land-use categories shown, and predominantly represent avoided emissions.

Table 2
Overview of Kyoto Art. 3.3 und 3.4 activities and conditions under which peatland drainage and rewetting need to be recorded and accounted for in the second commitment period of the Kyoto protocol (2013–2020).

Activity	*Emissions/removals have to be reported under this activity when*
Deforestation	• a forest on organic soils is felled and drained for conversion to agricultural land or pasture • timber harvesting increases water levels through reduced evapotranspiration such that forest regeneration is no longer possible • rewetting raises water tables to such an extent, that forest dies off • a peatland is rewetted and all remaining trees on the area are felled, e.g. to restore an open peatland, and tree regeneration is hindered through regular removal of saplings
Afforestation/Reforestation	• land (apart from forest) is drained for forestry, e.g. when soil with no or few trees is drained to promote tree growth • land (apart from forest) is rewetted for forestry, e.g. when grassland pasture is rewetted to plant alder trees
Forest Management	• a forest is drained and remains forest, e.g. when a wooded peatland is drained to increase timber production • a forest is rewetted but remains a forest, e.g. when an ash woodland is rewetted to be converted to an alder carr
Cropland Management (if elected[a]*)*	• land (apart from forest) is drained for conversion to agriculture • cropland is rewetted but remains cropland, e.g. when a farmed potato field is rewetted for paludiculture (wet agriculture)
Grazing Land Management (if elected[a]*)*	• land (apart from forest) is drained to increase pasture capacity • pasture land is rewetted but remains pasture, e.g. when a drained pasture for suckler cows is rewetted for water buffalo grazing
Revegetation (if elected[a]*)*	• land (apart from forest) is revegetated and rewetted, e.g. when an abandoned peat mining area is converted to a vegetated wetland
Wetland Drainage and Rewetting (if elected[a]*)*	• Land (apart from forest) that is not yet accounted for under another mandatory or voluntary activity is rewetted or drained since 1990

[a] If a party has already elected this activity for the first crediting period, reporting for the second crediting period is mandatory.

Table 3
Carbon market instruments and their application in the UK (AAU – assigned amount unit is a tradable 'Kyoto unit' or 'carbon credit' representing an allowance to emit GHG comprising one metric tonne of carbon dioxide equivalents calculated using their Global Warming Potential, ER – emission reduction, CER – certified emission reduction unit).

Carbon market instruments	**Evaluation for UK application**
Compliance markets	
(a) Kyoto protocol mechanisms (see Table 2)	In the second commitment period of the Kyoto Protocol (2013–2020) the UK must report and account for peatland rewetting (and drainage) under a series of land use activities (Afforestation, Reforestation, Deforestation, Forest Management) and can account it under other activities provided these are elected (Cropland Management, Grazing Land Management, Revegetation, Wetland Drainage and Rewetting)
• **International emissions trading (IET)** The UK could sell its surplus AAUs to a country with a deficit.	At present the UK has no surplus AAUs and has high internal targets. ERs from peatlands are not accounted and hence not tradable
• **Joint implementation (JI)** Annex I countries could finance a project in the UK and count the ERs in their national accounting.	JI rules imply that JI projects can only generate credits if carbon is sequestered (as opposed to emissions reduced). Therefore most peatland conservation and rewetting is not eligible as a JI project activity. Therefore this option is not popular among European countries. The UK currently does not allow JI credits to be sold and would lose any benefit from its own accounts
• **Clean development mechanism (CDM)** Annex I countries, e.g. UK, can fund projects in developing countries to receive CERs.	This option does not apply to projects within the UK
(b) EU emission trading scheme (ETS) cap and trade companies in major energy and industrial sectors buy from ER projects.	Article 24(a) of the EU ETS allows for the creation of domestic offsets from a wide range of activities that could include peatlands. However, the EC still has to make this, including the inclusion of LULUCF offsets operational
Voluntary carbon markets A company, government or an individual pays for a carbon credit to offset their emissions.	
(a) Over the counter market (OTC) bilateral agreements Projects are directly funded by business or via an Emission Reduction Purchase Agreement. Credits can be traded on the voluntary carbon market.	Several difficulties need to be overcome for UK implementation: (a) Current carbon prices do not meet UK restoration costs. Opportunities of bundling payments with co-benefits or funding alongside agri-environment schemes to be explored (both pillar 1 and pillar 1+2 payments) (b) National registry by approved UK body needed (c) Costs of verification through the international Verified Carbon Standard (VCS) are high in relation to project costs for small projects. Development of UK Peatland Carbon Code can facilitate cost-effective verification and reduce costs
(b) Exchange market exchanges set up to trade	Collapsed
(c) Regional carbon markets under **corporate social responsibility (CSR)** Companies or individuals acquire carbon credits to offset emissions in (voluntary) corporate carbon accounts and/or for good public relations. Any credits purchased are retired.	Regional markets - with sub-national level registries - replace the need for or can exist under a national registry. A template for the first regional carbon market for peatlands - MoorFutures in NE Germany - has already been developed. The approach should be scalable to any regions/countries that have degraded peatlands, access to these areas, and authorities that would act as registries for carbon credits. A similar regional scheme could be developed in the UK

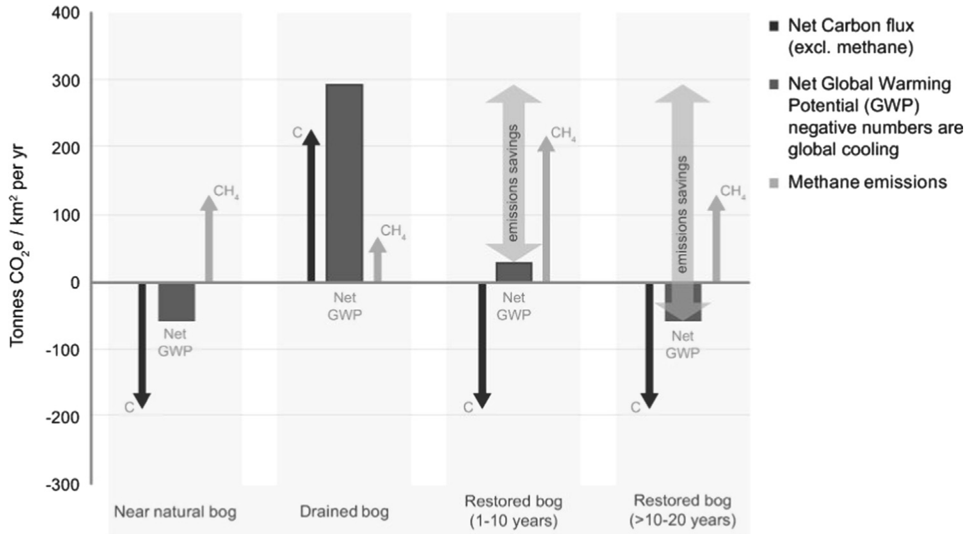

Fig. 1. Indicative Global Warming Potential (GWP) of UK blanket bogs under natural, drained and rewetted state. Rewetting results in at least 2.5 t CO_2e savings per ha per year (figures are illustrative, using conservative estimates; reproduction from Bain et al. 2011).

zone of aerobic decomposition, quickly turn peatlands into significant net GHG sources (e.g. Couwenberg et al., 2011, Evans et al., 2014). Pathways of carbon losses from peatlands include gaseous fluxes ('on-site emissions'), and also waterborne fluxes and/or biomass removals that can be converted to gaseous fluxes at a later stage ('off-site emissions'). Gaseous fluxes consist of losses of carbon dioxide (CO_2) through soil respiration under aerobic conditions (peat decomposition) and methane (CH_4) through activity of methanogenic bacteria under anaerobic conditions as well as nitrous oxides (N_2O). Waterborne fluxes consist primarily of export of dissolved organic carbon (DOC) from drainage waters and erosional losses of particulate organic carbon (POC), as well as losses of dissolved inorganic carbon (DIC), dissolved CO_2 and dissolved CH_4 (Billett et al., 2010; Worrall and Evans, 2009; IPCC, 2014).

Healthy peatlands provide a long-term sink for and store of carbon and have already for 10,000 years had a cooling effect on the climate (Frolking et al., 2006). In consequence, it is important first to safeguard pristine peatlands in order to maintain these ongoing functions. Drained and degrading peatlands are net GHG sources, and the second priority in managing peatlands for climate regulation should therefore be to reduce or reverse these emissions. While rewetting and restoration may increase CH_4 emissions in the short-term, this generally does not offset the immediate benefits of reducing oxidative carbon losses nor the long-term benefits of enhanced CO_2 sequestration, particularly if restoration is designed to encourage the re-establishment of *Sphagnum* species, which may reduce CH_4 emission from waterlogged peat (Gray et al., 2013; Cooper et al., 2014).

2.2. Mitigation potential of peatland restoration

Depending on the initial condition of the peat and form of peatland restoration, different GHG emission reductions can be achieved (Artz et al., 2012; IPCC, 2014). Especially rewetting of drained peatlands currently used as cropland can reduce GHG emissions substantially (Table 1). Similarly high reductions may be achieved by restoration of eroding bare peat sites, when re-vegetation rapidly limits erosion losses (POC) and re-instates primary productivity and CO_2 uptake within 2–4 years (Dixon et al., 2013; Waddington et al., 2010; Worrall et al., 2011b; Table 1). Re-initiation of true peat formation may, however, take decades. On moderately damaged peatlands restoration may lead to peat forming conditions more quickly, but associated emission reductions will be smaller (Artz et al., 2012; Komulainen et al., 1999). As noted above, CH_4 emission peaks following restoration can be minimised by effective restoration techniques, such as encouraging *Sphagnum* growth and limiting flooding (for discussion, see Evans et al., 2014). Fig. 1 provides an illustrative example and shows that emission reductions from a drained bog after ditch blocking of 2.5 t CO_2eq ha^{-1} yr^{-1}may be expected within the first 10 years whereas climate benefits of in total 3.1 t CO_2eq ha^{-1} yr^{-1} will occur when peatlands are re-stored to near natural conditions (Bain et al., 2011). For re-wetting drained peatlands under grassland or cropland, which is very relevant to European lowlands, the predicted emission savings are considerably larger, in the order of 20 t CO_2eq ha^{-1} yr^{-1} (Table 1).

The Intergovernmental Panel on Climate Change (IPCC) has recently prepared additional guidance on how to assess and report on emissions from organic soils and wetlands, including the rewetting of peatland (see Table 2 for relevant activities on peatlands). This involves providing default GHG emission figures associated with different water levels. This supplementary guidance (IPCC, 2014) forms the basis for future peatland GHG reporting and accounting under the UNFCCC and its Kyoto Protocol in Europe and elsewhere (see Section 4.4).

2.3. Extent and condition of peatlands in case studies

In the UK, deep peat and organic soils cover around 2.7 M ha, or 11% of the total UK land area, containing over 3200 ± 300 M t of carbon (Billett et al., 2010; Worrall et al., 2011a). Shallow peaty soils cover another 4.7 M ha. Over 80% of UK peatlands are in a degraded state (JNCC, 2011), mainly due to drainage, fire, grazing and afforestation, as well as atmospheric pollution (Bonn et al., 2009a; Holden et al., 2007). In line with national and international obligations on biodiversity and climate, such as the 2020 EU Biodiversity Strategy (European Commission, 2011), the IUCN UK Commission of Inquiry on Peatlands suggested as an actionable target of 1 M ha of peatlands in good condition or under restoration management by 2020 (Bain et al., 2011). This would meet the UK Biodiversity Action Plan targets for blanket and raised bog restoration (845,000 ha). Peatland restoration of blanket bogs therefore would provide a conservative abatement potential of 2.5 M t CO_2eq per year if the goal of 1 M ha restoration could be

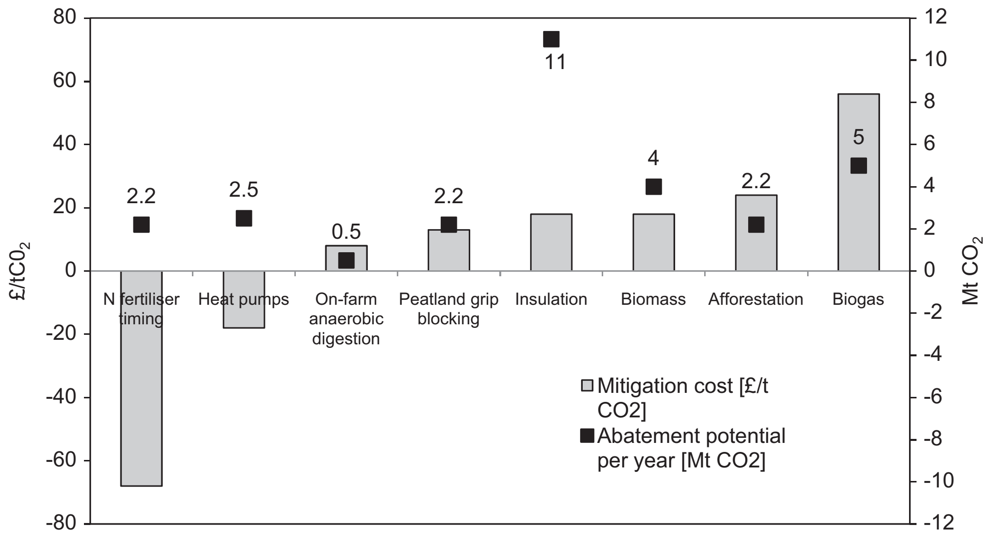

Fig. 2. Illustrative GHG mitigation costs and abatement potential of peatland restoration on UK blanket bog in relation to other measures (from Moxey 2011).

realised, while restoring drained lowland peatlands on cropland and grassland would lead to even higher reductions.

In Germany, peat soils store 1200–2400 M t of carbon on 1.4–1.8 M ha (Röder and Osterburg, 2012), i.e. around 5% of total German land area. Over 95% of former peatland habitats have been degraded, mainly through drainage for agriculture and forestry (Jensen et al., 2012). This leads to GHG emissions of 41 M t CO_2eq per year, which equates to 30% of the total GHG emissions from German agriculture or 4.4% of total GHG emissions from Germany (for overview, see Bonn et al., 2014). Peatland rewetting has been estimated to have an abatement potential of up to 5–35 M t CO_2eq per year for Germany (Freibauer et al., 2009).

3. Policy and market background

3.1. International climate change policy and peatlands

UNFCC is the international process that provides a regulatory framework for action to reduce GHG emissions. Under this treaty, the Kyoto Protocol sets mandatory emission limits and reduction targets for developed nations for the first commitment period (2008–2012) and the second commitment period (2013–2020), and defines which activities have to be accounted for as emission or removal. For the first commitment period, the Kyoto Protocol and relevant delegated legislation prescribed that countries must account for emissions and removals from afforestation, reforestation and deforestation (in line with Article 3.3) and allowed for accounting for forest management, cropland management, grazing land management and re-vegetation on a voluntary basis (in line with Article 3.4). At the 17th Conference of the Parties (COP17) to the United Nations Framework Convention on Climate Change, parties to the convention agreed to recognize *Wetland Drainage and Rewetting* (WDR) as a specific new activity under Article 3.4 of the Kyoto Protocol, which may be accounted for on a voluntary basis during the second commitment period. This is an important decision, giving further legitimacy to peatland restoration as a climate mitigation activity. As a voluntary activity, it is for individual Governments to decide whether to incorporate this activity from 2013 onwards in their international GHG accounting. Emission reductions from any restoration carried out since 1990 may be accounted for. In return, any new drainage undertaken since 1990 will also have to be taken into account. Most peatland drainage in Europe pre-dates the 1990 base year and was associated with agricultural subsidies and forest policies. Therefore, the main impact of adopting the new category would be to allow peatland restoration projects to contribute to country's climate change targets (see Table 2 for details, as the practices “draining” and “rewetting” have to be reported and accounted in a wide range of other activities (IPCC, 2014)).

3.2. Market options for peatland restoration

As evidence of the impacts of peatland degradation has become clearer, interest has grown in the potential to stimulate private investment for peatland restoration through carbon markets (Dunn and Freeman, 2011; Worrall et al., 2009). There are several options for funding peatland restoration. Broadly speaking, they differ in the extent to which: (i) they pay solely for carbon and climate mitigation benefits, or pay for a wider range of ecosystem services derived from restoration; (ii) they are publically versus privately funded; and (iii) they are international or regional in scope. The compliance carbon market (established via the Kyoto Protocol) is an example of an international part public/part private-funded mechanism, primarily for climate mitigation, though co-benefits can be included, e.g. in Clean Development Mechanisms projects. Compliance carbon markets under the Kyoto Protocol based on its flexibility mechanisms (International Emissions Trading, Joint Implementation, and Clean Development Mechanism) currently have limited opportunities to apply to land use projects in the UK and Germany.

Voluntary carbon markets are based on private funding, primarily for climate mitigation benefits, but generally with a greater emphasis on co-benefits than the compliance market. Regional voluntary carbon markets may be national or refer to one region within a country in scope, and typically target national or regional investors to contribute towards local restoration schemes (Kossoy and Guigon, 2012). Although they develop their own regional standards, they may draw on and adapt existing standards from the international carbon market.

Finally, agri-environment schemes across Europe provide a major avenue to channel public funding into national peatland restoration (Reed et al., 2014). These schemes are justified on the basis of paying for the fullest possible range of ecosystem service benefits (although as Reed et al., 2014, point out, these are often quite poorly quantified, see Fig. 3).

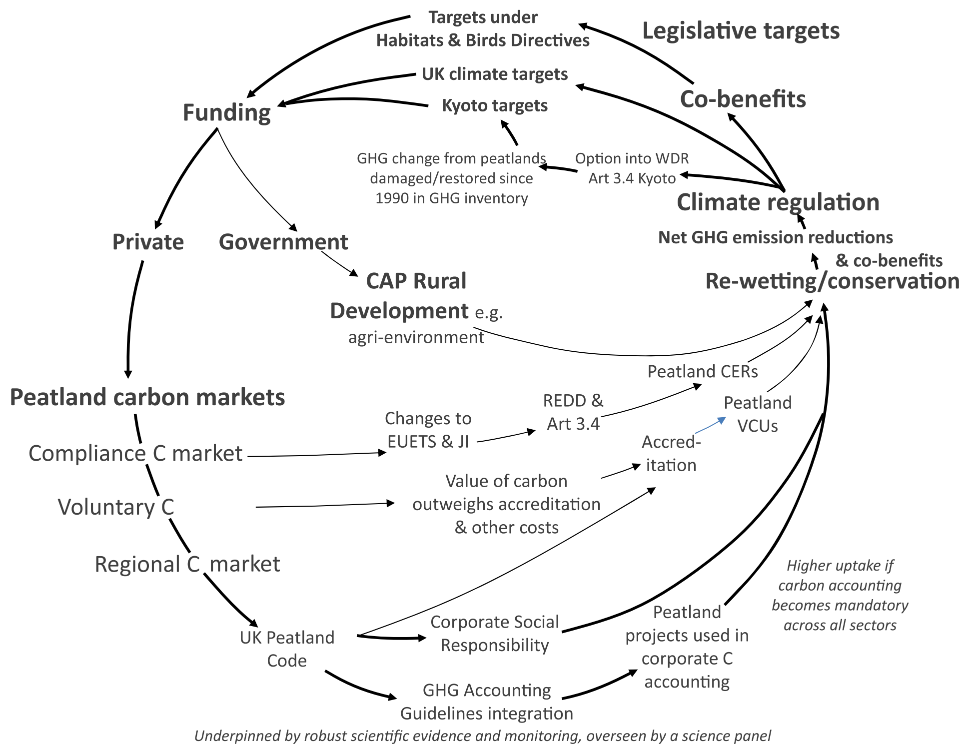

Fig. 3. Options for public and private financing of peatland rewetting (VCUs - Verified Carbon Units; CAP - Common Agricultural Policy; CERs - Certified Emission Reductions; REDD - Reducing Emissions from Deforestation and Forest Degradation; EU ETS - European Union Emission Trading Scheme; VCS - Verified Carbon Standard, WDR - Wetland Drainage and Rewetting).

The global voluntary carbon market was valued at $569 million in 2011, which is significantly smaller in value compared to the compliance market with a value of $149 billion in 2011 (Kossoy and Guigon, 2012). Currently, however, in practical terms, the voluntary market is the main market that can provide direct finance to peatland projects (Tanneberger and Wichtmann, 2011; Joosten et al., 2012). Actual funding for peatland restoration via this market has been slow to take off; it was less than €0.5 M in a two year period for both MoorFutures projects in NE Germany, and the UK scheme has yet to be implemented (see below).

Peatlands are already eligible under existing standards for the voluntary market, i.e. the Verified Carbon Standard (VCS http://www.v-c-s.org/) and the Climate Community and Biodiversity Standard (CCBS http://www.climate-standards.org/).The dominant VCS provides general standards for land-based climate change mitigation projects, and can now be used also to verify changes in GHG fluxes resulting from peatland restoration projects. In 2012, the VCS programme approved a new set of *Wetland Restoration and Conservation* (WRC) requirements that are fully inline with other Agriculture, Forestry and Other Land Use (AFOLU) activities. A new AFOLU category – the *Rewetting of Drained Peatlands* (RDP), as sub-category of Restoration of Wetland Ecosystems (RWE) – is now part of the standard. Verification and accreditation via the VCS, however, can be costly and financially only feasible for large-scale projects or big investors.

For this reason, regional carbon markets are emerging, with their own standards (often based on VCS guidance), which are sufficiently rigorous for investors in that region, but that are more cost-effective to implement than VCS standards (see e.g. Boxes 1 and 2). Such regional schemes also have the advantage of being tailored to the specific regional context, which may enable them to offer more rigorous standards. For example, regional schemes are more likely to be able to verify GHG emission reductions on the basis of empirical or modelled measurements rather than using IPCC default values, and may be able to better identify potential trade-offs with other ecosystem services provided by the project area.

3.3. *Market demand for peatland restoration*

There is growing interest in developing a regional market for peatland restoration in the UK (Reed et al., 2013), Germany (Joosten et al., 2013a) and elsewhere, due to its cost effective climate mitigation and abatement potential, comparable to other measures (Fig. 2). In the UK, the government is supporting companies and businesses, who wish to register their own corporate GHG emissions, and is considering making such reporting mandatory. At present, the possibility to use peatland restoration for carbon offsetting is not yet included in the Governments guidance on corporate GHG reporting (the Environmental Reporting Guidelines -Defra, 2013). However, it may be possible to add an annex that would allow companies to invest in peatland restoration as part of their efforts to become carbon neutral under these guidelines in future. It is to be noted, that carbon markets based on land use offsetting projects face opposition from major climate and environmental organisations in view of perceived lack of regulation and scientific uncertainties.

To investigate demand from business for peatland restoration, Reed et al. (2013) interviewed representatives from a sample of 15 businesses from a broad range of sectors in the UK that were either currently investing in land-based carbon projects, or had the potential to do so (there was a focus on the corporate sector, and three interviews were conducted with small to medium enterprises, SMEs). Broadly speaking, there were two types of potential investors: (i) multi-nationals with UK brand identity, and a substantial UK customer and/or employee base in relatively close proximity to peatland restoration sites who wished to build brand awareness and loyalty; and (ii) SMEs with brand or product lines

Box 1–MoorFutures® – a regional carbon market in Germany

The MoorFutures® voluntary carbon market was launched in 2011 to support peatland restoration in a particular region of NE Germany, the federal state of Mecklenburg-Vorpommern (MLUV, 2009). It is now implemented also in two other federal states, and more states are considering to follow. The MoorFutures Standard has been developed based on the Verified Carbon Standard (VCS) Wetland Restoration and Conservation (WRC) guidance. While applying the VCS methodology would be too expensive in Mecklenburg-Vorpommern, as sites are relatively small, the MoorFutures Standard has been developed to suit specific regional conditions and is therefore more cost efficient to implement.

Additionality of MoorFutures is secured as restoration projects can only be realised through the finance generated through the MoorFutures credits. To allow for transparency and to avoid double counting MoorFutures credits are retired and recorded in a federal state registry with a specific series number. Using the series number investors and their customers can easily establish how many emission reductions have been retired, and this state registry can also be incorporated in business communication strategies. By June 2014, about 10,000 credits have been sold.

MoorFutures credits are based on realistic estimates of emissions before and after rewetting using the GEST approach (see Section 4.4). Measuring of gas fluxes at demonstration sites for these site types ensures that emission data are open to scrutiny and verifiable. To estimate emission reductions, MoorFutures uses a forward looking baseline, i.e. the results of a 'with project' scenario are compared with the reference scenario that would have occurred without implementation of the project. Reductions in N_2O emissions with rewetting are not included, and potential depletion of peat in the baseline is taken into account, i.e. emission reductions for areas with thin peat layers are only calculated as long as they would not have been exhausted by continued decomposition without rewetting.

The permanence of MoorFutures is guaranteed through (a) prescribed water levels under the Water Law, (b) entries in the land register to secure permanence of the required water levels and/or (c) the purchase of land for restoration through the 'Stiftung Umwelt- und Naturschutz Mecklenburg-Vorpommern' trust that can guarantee the long-term maintenance and management of project sites. Recently a *MoorFutures*2.0 version has been developed to integrate also other ecosystem services, such as nutrient retention or habitat provision for biodiversity (Joosten et al., 2013a).

For more information, visit: http://www.moorfutures.de

Box 2–The Peatland Code – a pilot regional carbon market for the UK

The pilot Peatland Code is a voluntary standard for sponsoring peatland restoration projects in the UK on the basis of their climate and other benefits (Reed et al., 2013). It is designed to ensure the highest environmental standards and assurances on the carbon and other benefits of the peatland restoration work. It gives guidance to those undertaking restoration, and gives sponsors confidence that their contribution is making a measurable, verifiable and lasting difference to UK peatlands. By sponsoring peatland restoration, businesses can enhance their brand integrity and value, deliver corporate sustainability objectives and contribute strategically to the long-term protection and enhancement of some of the UK's most iconic landscapes.

The pilot Peatland Code was launched in September 2013 for an initial 18 month period, and includes a number of pilot peatland restoration projects as part of the pilot phase. The Code is owned by the International Union for the Conservation of Nature (IUCN)'s UK National Committee and is directed by a Steering Group with inputs from a technical sub-group. It defines eligibility criteria for projects in terms of the types of site and activities permitted and a number of additionality criteria that projects must meet. The Peatland Code sets out principles, requirements and guidance for the eligibility of projects, how projects are governed and documented, and how the climate and other benefits of restoration should be monitored

At this stage the Pilot Phase Code is designed to facilitate business sponsorship motivated by corporate social responsibility; it is not yet intended for use in formal offset schemes, corporate carbon reporting or to be traded on international carbon markets. The Code does provide guidance on quantifying climate and other benefits, to reinforce the value of the sponsoring restoration, and it may be possible to count these benefits in corporate carbon accounts in future if Government guidelines allow. However, initially the Pilot Phase will focus on validating and certifying peatland restoration projects in selected pilot areas to help demonstrate peatland benefits and build an increasingly robust evidence base and methodology for future phases of Code development.

To find out more about the Peatland Code, visit: http://www.iucn-uk-peatlandprogramme.org and follow links to the Peatland Code. Alternatively, see Reed et (2013) for full details of how the Code was developed, consultation feedback and responses and market research.

linked to peatlands e.g. food and drink, hospitality/tourism. Many multi-nationals were interested in the possibility of using peatland carbon for future carbon trading and corporate carbon accounting. However, for corporations with large emissions, the co-benefits of peatland restoration were more important than the climate benefits per se, as these would only ever represent a very small fraction of their overall emissions profile. Similarly, SMEs were more interested in the full range of benefits arising from peatland restoration that they could use to help market specific products, rather than being narrowly focussed on the climate benefits. Having said this, all respondents in this study were particularly interested in the carbon benefits, and wanted rigorous quantification of these benefits. This was followed by interests in biodiversity, and water quality benefits (especially for companies with large water usage). However, given the likely additional costs of quantifying these co-benefits, respondents were content for them to be underwritten by an expert panel or a well-known NGO who they would trust to deliver such benefits.

Sectors with particular interest in financing peatland restoration included: food & drink (marketing brands and product lines linked to peat/uplands e.g. hill bred lamb, spring water products, whisky etc.); hospitality/tourism linked primarily to upland peatlands; energy (compensating damage from infrastructure development); water (capturing the carbon benefits of restoration being undertaken for water quality benefits); and horticulture (in particular enhancing peat-free compost brands). Respondents were generally prepared to pay a premium for national (UK) projects that could provide multiple-benefits in addition to climate change mitigation. There was no desire to see a fixed price for carbon in peatland restoration projects; rather respondents expected pricing to reflect the location and range of co-benefits that they could link to different product lines. No transactions have yet taken place under the UK Peatland Code, which is currently still in its pilot phase with the first projects under validation.

4. Developing regional carbon markets to restore peatlands

4.1. Regional peatland carbon markets

To develop regional carbon markets to restore peatlands, both peatland managers and investors require a system in place that provides standards, verification and accreditation, combined with an effective and standardised methodology for estimating emissions reductions under different peatland management regimes. This section of the paper draws on experience developing regional carbon markets for peatlands for the UK and NE Germany to distil widely applicable lessons for the development of these markets elsewhere internationally. Specifically, we consider lessons for additionality, permanence, monitoring and co-benefits. First, we provide an overview of how each of these voluntary standards operate (see Boxes 1 and 2). MoorFutures in Germany and the pilot UK Peatland Code are each voluntary standards that provide businesses with the opportunity to invest in land-based GHG emission reductions as part of their CSR portfolios. Because they are consistent with international standards, it may be possible to include them in national GHG reporting and voluntary carbon trading markets at a later stage.

4.2. Approaches to additionality

To attract investment, regional carbon markets must demonstrate that the projects they fund would not have occurred without investment from sponsors, i.e. they are “additional”. Broadly speaking, four types of additionality tests can be seen across the regional carbon markets assessed in this paper:

- **Legal Test**: the project would not be considered additional if there is a pre-existing legal order specifying that peatland should be restored (e.g. planning conditions). Restoration is considered additional on sites with conservation designations, where there are objectives to restore peatland, but where finance has hitherto been and is expected to remain unavailable to achieve these objectives, and where there are no statutory orders requiring action e.g. nature conservation orders under legislative Acts.
- **Contribution of Carbon Finance Test**: the project would only be considered additional if it could not have happened without peatland restoration sponsorship. However projects do not have to be entirely funded on this basis, so schemes may set a threshold for the contribution of sponsors (e.g. 15% of project costs in the UK's Peatland Code).Where additional funding is to be sourced from other public funds (e.g. from agri-environment schemes), projects must confirm that a certain proportion (e.g. at least 15%) of project costs will come from private peatland restoration sponsorship.
- **Investment test**: projects need to demonstrate that without carbon finance the peatland restoration project is either not the most economically or financially attractive for that area of land or is not economically or financially viable on that land at all. For example, in the absence of peatland restoration sponsorship, existing financial incentives (e.g. from agri-environment schemes) may be insufficient to make the restoration project financially viable, or existing or alternative land uses that preclude restoration may be more attractive financially, and so prevent restoration taking place.
- **Barrier test**: in the absence of peatland restoration sponsorship, other barriers may prevent restoration from taking place e.g. lack of community buy-in, inaccessibility, lack of skilled labour and inputs, insufficient finance to meet up-front costs. If sponsorship can help overcome these barriers and make restoration viable, then the project would be considered to be additional.

It may be possible to simplify these additionality tests by providing standardised additionality criteria for different types of project activity, i.e. projects demonstrating that they meet the conditions and criteria set out for the specific project class are automatically deemed additional. Standardised approaches to additionality have been recently incorporated into the VCS Standard and are expected to streamline project development without undermining their credibility.

4.3. Approach to permanence

One of the main perceived drawbacks of land-based climate mitigation activities is their potential reversibility and non-permanence of carbon stocks as a result of human activities, natural disturbances, or environmental change, including climate change. Risks to the permanence of peatland projects may include:

- **Internal risks to the project**, such as: project management risks (e.g. lack of qualified personnel to undertake the restoration work, issues over enforcing property rights, and inappropriate selection of management techniques); and financial risks (e.g. lack of sufficient funds to meet all project costs or significant opportunity costs); reversal of land management back to drainage and intensive land use (decision by land manager, if insufficient legal contract);
- **External risks to the project**, such as: land tenure and resource access, and the threat that competing uses of land can have to the restoration project (e.g. public access may cause erosion and peatland degradation); lack of community ‘buy-in’ to the project; and negative impacts on adjacent landholdings; and
- **Natural risks to the project**, such as: wildfire; extreme weather; climate change; impact of tree planting or drainage on adjacent land within the same hydrological unit; and geological risk including slope-failure, mass movements/peat slides.

Carbon standards in the voluntary market, such as the Verified Carbon Standard (VCS), therefore require safeguards, such as a buffer reserve, to address non-permanence for project activities. The buffer is defined as ‘a pool of unclaimed GHG emission reductions’ to cover either uncertainty in GHG measurement or unavoidable potential losses which may occur from the project over time, thus ensuring the permanence of GHG emission reductions.

There is an essential distinction between carbon sinks and emission reductions by sequestration projects and emission avoidance projects used as offsets for industrial emissions. We distinguish two cases:

- Case 1 **Reversal in a carbon sequestration project** (Fig. 4a): A reversal in activities such as afforestation and reforestation (A/R) negates the effect the sink had. There is no significant long-term mitigating effect on climate change as eventually the atmospheric CO_2concentration has not been reduced.
- Case 2 **Temporary emission reduction** (Fig. 4b): A termination of the emission reduction in a REDD (Reducing Emissions from Deforestation and Forest Degradation) project or a peatland rewetting project does not cancel the effect the emission reduction has had so far, as the CO_2concentration in the atmosphere is reduced permanently. This will be the case in an avoided forest degradation project where for a number of years degradation is stopped but then continues at the same

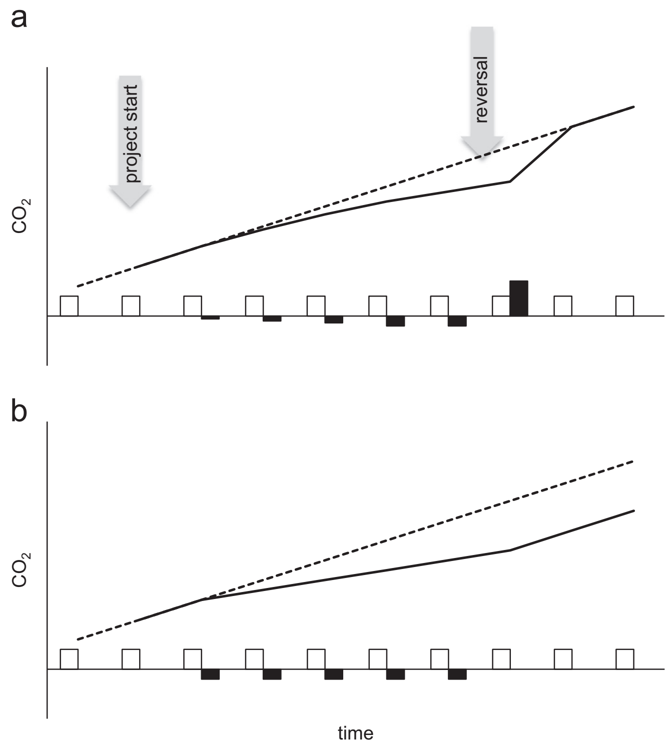

Fig. 4. a and b: Development of CO_2 concentrations in the atmosphere along a hypothetical time line for (a) a sink project (e.g. afforestation) and (b) an avoidance project (e.g. peatland rewetting). (white bars – industrial emissions, assumed to be constant; black bars – CO_2 removals and emission avoidances, respectively, from the project and the subsequent emission by reversal; dotted line – CO_2 concentration in the atmosphere without project (baseline); black line – CO_2 concentration in the atmosphere with project).

rate as before, or in a peatland rewetting project where CO_2 emissions had been stopped but subsequently re-start due to a failure of dams built by the project.

If in case 1 the reversal occurs after a sufficiently long period of time (e.g. 50 years) a climate benefit is achieved until that moment and is then reversed (non-permanent). It is a policy decision whether or not to credit these temporary climate benefits.

In case 2 there is no issue of non-permanence. Achieved emission reductions from peatland restoration projects have the same climate effect as any other emission reductions (e.g. reduced fossil fuel use) and are not negated when the annual emission reductions stop. Therefore, it may not be necessary for future regional markets for climate mitigation via peatland restoration, which aim to reduce emissions, to require permanence.

The traditional way to ensure permanence of emission reduction or removals in existing standards such as the VCS, MoorFutures and the UK's Peatland Code is through requirements for project design, longevity of legal constructions and the assessment of non-permanence risk factors. In such a manner, the permanence of MoorFutures is guaranteed through: (a) prescribed water levels under the Water Law; (b) entries in the land register to secure permanence of the required water levels; and/or (c) the purchase of land for restoration through e.g. the 'Stiftung Umwelt- und Naturschutz Mecklenburg-Vorpommern' trust that can guarantee the long-term maintenance of project sites (see Box 1). For the UK Code, legal ownership or tenure of the project area for the duration of the project must be demonstrated by a signed attestation, title deeds, as solicitor's letter, or evidence of long-term unchallenged use. However, as outlined above, such approaches may become obsolete, if it is accepted that emission reductions in peatland restoration do not have permanence issues.

4.4. Monitoring

Robust monitoring of GHG emission benefits is essential to underpin the operation of any regional carbon market, but doing this in a cost-effective way for sponsors can present challenges. Unlike the measurement of carbon stock changes in woodlands, changes in GHG emissions after peatland restoration are highly variable over space and time. As such, the costs are prohibitive when considering direct measurements or the development of process-based computational models that have to be calibrated to sites and validated against sampled data.

For this reason, proxy variables have been developed for assessing GHG fluxes to support the operation of peatland carbon markets. Most GHG emissions from peatlands are closely correlated with water table, either directly or indirectly via the effects of water table (in semi-natural ecosystems) on species assemblage. These functional relationships have underpinned the development of the *Greenhouse gas Emission Site Types* (GEST) approach for continental Europe, which provides proxy estimates for GHG emission from peatlands (Couwenberg et al., 2011). Couwenberg et al. (2011) developed a matrix system that classifies vegetation assemblages, according to their relationship with water table levels and the presence of aerenchymous species, whilst also considering nutrient status, pH and land use into GESTs. The GEST approach allows for a rapid baseline assessment of GHG fluxes from peatland sites in their current state and offers more detailed assessments than current IPCC default values (Couwenberg, 2011). A carbon accounting methodology for peatland rewetting projects based on the GEST approach has been recently developed (O'Sullivan and Emmer, 2011) and is under assessment by the Verified Carbon Standard (http://www.v-c-s.org/rewetting_drained_peatlands_GEST). A similar, parallel development in the UK, focusing directly on ecosystem function and GHG flux pathways (and less on water table levels, which are less useful as a proxy for blanket bogs), has led to the development of Standard Emissions Values for different blanket bog states (Birnie and Smyth (2013))

Both MoorFutures and the UK Peatland Code use the GEST approach to estimate emissions before and after rewetting. Measuring of gas fluxes at demonstration sites for these site types ensures that emission data are open to scrutiny and verifiable. To estimate emission reductions, both schemes use a forward looking baseline, i.e. the results of a 'with project' scenario are compared with the reference scenario that would have occurred without implementation of the project. Reductions in N_2O emissions with rewetting are not included in either scheme, but in MoorFutures the potential depletion of peat in the baseline is taken into account, i.e. emission reductions for areas with thin peat layers are only calculated as long as they would not have been exhausted by continued decomposition without rewetting. Monitoring needs to be carried out at regular intervals to verify the projected development after rewetting, and emission estimates may be adapted to improved scientific evidence on an ongoing basis. Verification of the climate benefits of restoration needs to be undertaken by an accredited body that can also ensure that the peatland is being managed appropriately.

To quantify emission reductions for carbon markets, data on GHG emissions before and after peatland restoration are needed. Measuring emissions from individual peatland sites, however, is challenging and expensive, but proxy methods for monitoring complete carbon budgets are available (Billett et al., 2010). The IPCC Guidelines provide typical default Tier 1 emissions factors from organic soils for different land use categories, such as forest land, cropland and grassland (IPCC, 2014). These Tier 1 emission factors, which are designed for global application across wide climate, soil and land-use categories, could be used for carbon payment schemes for peatland restoration, but provide limited scope to reflect the specific conditions within individual countries. For example, temperate and boreal peatlands are differentiated only at the level of 'nutrient rich' (fen) and 'nutrient poor' (bog), without specific consideration of the (different) functioning of blanket bogs which predominate within the UK. No emission values are provided for undrained but managed organic soils such as blanket bogs under burn management for game birds. To achieve reliable emission reduction estimatesfor peatland carbon markets,it is good practice for organic soils to replace the default Tier 1 values with country- or region-specific factors, Tier 2, or to apply a Tier 3 approach (using more detailed, dynamic accounting methods or modelled data) (IPCC, 2014).

4.5. Co-benefits

Peatland restoration has a range of substantial co-benefits, including biodiversity gains, improved water quality, reduced wildfire risk, and aesthetic and accessibility benefits for recreation (see e.g. Joosten et al., 2013a). However, peatland restoration may also lead to undesirable trade-offs, which may need to be minimised through proactive land management planning, either via mitigation measures or additional payments to compensate for lost income (e.g. where restoration requires reducing the intensity of livestock grazing, or the cessation of arable cultivation). Basic peatland restoration can also provide a foundation for other biodiversity creation or restoration projects and, where this land management is additional to the peatland restoration, such management could access other income streams such as biodiversity offsetting funding.

In addition to helping meet climate targets, these co-benefits may help meet other policy targets e.g. under the EU Habitats Directive or Water Framework Directive. Given that investments in carbon are often made as part of a portfolio of CSR activities, market research by BRE (Rabinowitz and d'Este-Hoare, 2010) suggests that these co-benefits are likely to be valued by investors, who are often prepared to pay extra to secure these other benefits. Voluntary standards therefore have to provide safeguards to ensure investments in peatland carbon do not come at the expense of other important ecosystem services, and schemes may be able to provide guidance to optimise the range of co-benefits that can be obtained from carbon-based schemes.

There are two ways in which these co-benefits may be captured and monetised as part of a peatland carbon scheme: bundling and layering. Bundling is defined as grouping multiple ecosystem services together in a single package to be bought by individual or multiple buyers (Lau, 2013). For example, it may be possible to bundle carbon, water quality, biodiversity, visitor benefits and wildfire risk benefits together in a single scheme designed to pay for peatland restoration. "Layering" (also called "stacking") refers to schemes where payments are made for different ecosystem services separately from the same system. For example, the same peatland restoration project could run a carbon offset scheme in parallel with a scheme targeting water companies to pay for water quality benefits, whilst taking in money from a visitor payback scheme. Sometimes it is not possible to capture payments for all the co-benefits of a scheme. This is often referred to as "piggy-backing", where payments for one ecosystem service lead to the production of additional services for free.

Layering may lead to double-counting (for example paying for the peatland restoration many times over on the basis of different benefits), and it assumes that services are produced independently, and that each service can be clearly delineated and quantified separately (Kosoy and Corbera, 2010). However, where bundling is not deemed suitable or feasible, or where no buyer can be found for a bundle of services, then layering (with careful quantification) may provide the co-ordination necessary to avoid trade-offs between ecosystem services (Lau, 2013). Whether for this reason or to meet regulatory requirements (e.g. water quality targets) it is desirable to be able to "un-bundle" ecosystem services if necessary (Deal et al., 2012).There are likely to be higher costs associated with setting up multiple schemes in parallel, but where existing schemes are already running (e.g. a water company paying land managers to produce clean water via peatland management), it may be attractive to introduce separate schemes for additional services over time in response to market demand. For example, it may be possible to introduce a carbon scheme to support investment to help pay for the carbon benefits of managing land for clean water. This is likely to be particularly useful where the costs of restoration cannot be met through payments for carbon or water alone (e.g. in highly damaged or inaccessible peatlands where restoration costs are high), or where land owners are not prepared to restore peatland purely on the basis of covering their costs. By bundling or layering payments for different services together, a greater proportion of the overall societal benefits of restoration schemes can be effectively monetised, providing greater opportunity to meet the costs of restoration, and additional incentives to induce land owners to join the scheme.

5. Conclusions

To meet the challenge of proactive ecosystem restoration and ecosystem based mitigation and adaptation, new and enhanced sources of investment are needed. Well-designed agri-environment schemes are needed (Reed et al., 2014) as well as market-based instruments that may leverage private sector funding and that, if combined, may provide strong economic incentives for action. Here, we have outlined the lessons from developing a robust market instrument that provides stakeholders – land users and owners, investors, public co-funders, dedicated interest groups – with reliable standards, thorough verification, accreditation and carbon crediting services, and well-designed, accurate and cost-effective methodologies for verifying emissions reductions under different peatland management and restoration regimes. These can help to achieve a double-objective: increasing the funds available for restoration action and improving the transparency of action.

The requirements for developing regional carbon markets outlined in this paper demonstrate the necessary scientific evidence and policy frameworks needed to develop ecosystem service markets for peatland restoration. Although this paper has focussed on the UK and German context, it draws on international experience, and is likely to be directly applicable to peatlands across Europe and North America. Many of the lessons that are being learned in the development of the peatland carbon code are also likely to be relevant for the creation of regional carbon markets for other peatlands across the globe.

Carbon markets are particularly appealing for payments for ecosystem service schemes, as climate regulating services through carbon credits lack a spatial-dependence (Glenk et al., 2014), i.e. benefits are experienced globally regardless of the location of the restoration action. To develop carbon markets it is of high importance to employ a well-defined, widely accepted, transparent and verifiable methodology. While it is possible to use global standards, the development of regional standards can avoid high verification costs and also provide a close link to regional natural capital for investors. However, there is a need for a strong evidence base to support the methodology (Evans et al., 2014). For developing market-based approaches to ecosystem restoration it is beneficial to ground these within national and international protocols, such as the Kyoto Protocol, to give credibility, integration with government policy, and link with action targets of different sectors. Marketability of restoration can be increased if a regional link is maintained and if multiple ecosystem service benefits are bundled, as evident from the reported market research rather than just considering single services such as climate regulation. However, we need to accept that ecosystem-based mitigation and adaptation approach to peatland restoration with a focus on climate regulation will not always be optimal for biodiversity targets. Here, a balance needs to be found through analysis of synergies and trade-offs of biodiversity and ecosystem service provision.

Scientific challenges remain to provide a cost-effective verification of baseline emissions and likely emission reductions over the duration of restoration projects. While the recently published guidance on IPCC accounting methodology for peatlands (IPCC, 2014) provides a basis for verification, and ongoing flux measurement programmes contribute to estimate emissions factors for different peatland management activities and ultimately the development of model-based approaches, the development of GHG emission proxies is needed. This could be achieved through the adaptation of the vegetation-based Central European GEST model (Couwenberg et al., 2011) for regional conditions of peatlands across Europe and N-America, and development of associated remote sensing techniques to monitoring vegetation change.

Working closely in a transdisciplinary networks bringing together experts from the natural and social sciences, policy and land management practitioner communities, business and carbon market consultants to assess the potential for valuing and investing in nature, has allowed to develop new carbon market schemes through peatland codes, both in Germany and the UK, and we hope this process can provide inspiration for imitation.

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References

Artz, R.R.E., Chapman, S.J., Donnelly, D., Matthews, R., 2012. Potential abatement from peatland restoration. Briefing Note to Scottish Government.

Bain, C., Bonn, A., Stoneman, R., Chapman, S., Coupar, A., Evans, M., Geary, B., Howat, M., Joosten, H., Keenleyside, C., Lindsay, R., Labadz, J., Littlewood, N., Lunt, P., Miller, C., Moxey, A., Orr, H., Reed, M.S., Smith, P., Swales, V., Thompson, D.B.A., Van de Noort, R., Wilson, J.D., Worrall, F., 2011. Commission of Inquiry on UK Peatlands. IUCN UK Peatland Programme, Edinburgh.

Billett, M., Charman, D.J., Clark, J.M., Evans, C., Evans, M., Ostle, N., Worrall, F., Burden, A., Dinsmore, K., Jones, T., McNamara, N., Parry, L., Rowson, J., Rose, R., 2010. Carbon balance of UK peatlands: current state of knowledge and future research challenges. Clim. Res. 45, 13–29.

Birnie, R.V., Smyth, M.A., 2013. Case study on developing the market for carbon storage and sequestration by peatlands. Crichton Carbon Centre.

Bonn, A., Allott, T., Evans, M., Joosten, H., Stoneman, R., 2014. Peatland Restoration for Ecosystem Services. Cambridge University Press, Cambridge, in press.

Bonn, A., Berghöfer, A., Couwenberg, J., Drösler, M., Jensen, R., Kantelhardt, J., Luthardt, V., Permien, T., Röder, N., Schaller, L., Schweppe-Kraft, B., Tanneberger, F., Trepel, M., Wichmann, S., 2014. Klimaschutz durch Wiedervernässung von kohlenstoffreichen Böden. In: Hartje, V., Wüstemann, H., Bonn, A. (Eds.), Naturkapital und Klimapolitik - Synergien und Konflikte. Naturkapital Deutschland TEEB DE Report. Technische Universität Berlin Helmholtz-Zentrum für Umweltforschung - UFZ, Berlin, Leipzig.

Bonn, A., Allott, T., Hubacek, K., Stewart, J., 2009a. Drivers of Environmental Change in Uplands. Routledge, London and New York.

Bonn, A., Rebane, M., Reid, C., 2009b. Ecosystem services: a new rationale for conservation of upland environments. In: Bonn, A., Allott, T., Hubacek, K., Stewart, J. (Eds.), Drivers of Environmental Change in Uplands. Routledge, London and New York, pp. 448–474.

Clymo, R.S., 1984. The limits to peat bog growth. Philos. Trans. R. Soc. B: Biol. Sci. 303, 605–654.

Cooper, M., Evans, C.D., Zieliński, P., Levy, P.E., Gray, A., Peacock, M., Fenner, N., Freeman, C., 2014. Infilled ditches are hotspots of landscape methane flux following peatland restoration. Ecosystems 10.1007/s10021-014-9791-3, in press.

Couwenberg, J., 2011. Greenhouse gas emissions from managed peat soils: is the IPCC reporting guidance realistic? Mires and Peat 8, Article 02, pp. 01–10.

Couwenberg, J., Thiele, A., Tanneberger, F., Augustin, J., Bärisch, S., Dubovik, D., Liashchynskaya, N., Michaelis, D., Minke, M., Skuratovich, A., Joosten, H., 2011. Assessing greenhouse gas emissions from peatlands using vegetation as a proxy. Hydrobiologia 674, 67–89.

Deal, R.L., Cochran, B., LaRocco, G., 2012. Bundling of ecosystem services to increase forestland value and enhance sustainable forest management. Forest Policy Econ. 17, 69–76.

Defra, 2013. Environmental Reporting Guidelines: Including Mandatory Greenhouse Gas Emissions Reporting Guidance. Department for Environment, Food and Rural Affairs, London.

Dixon, S.D., Qassim, S.M., Rowson, J.G., Worrall, F., Evans, M.G., Boothroyd, I.M., Bonn, A., 2013. Restoration effects on water table depths and CO_2 fluxes from climatically marginal blanket bog. Biogeochemistry, 1–18.

Dunn, C., Freeman, C., 2011. Peatlands: our greatest source of carbon credits? Carbon Manag. 2, 289–301.

European Commission, 2011. Our life insurance, our natural capital: an EU biodiversity strategy to 2020. Communication from the Commission to the European parliament, the council, the economic and social committee and the committee of the regions. COM 2011, 244 final.

Evans, C.D., Bonn, A., Holden, J., Reed, M., Evans, M., Worrall, F., Parnell, M., 2014. Relationships between anthropogenic pressures and ecosystem functions in UK blanket bogs: linking process understanding to ecosystem service valuation. Ecosyst. Serv. 9, 5–19, http://dx.doi.org/10.1016/j.ecoser.2014.06.013.

Freibauer, A., Drösler, M., Gensior, A., Schulze, E.-D., 2009. Das Potenzial von Wäldern und Mooren für den Klimaschutz in Deutschland und auf globaler Ebene. Nat. Landsch. 84, 20–25.

Frolking, S., Roulet, N., Fuglestvedt, J., 2006. How northern peatlands influence the Earth's radiative budget: sustained methane emission versus sustained carbon sequestration. J. Geophys. Res. 111, G01008.

Glenk, K., Schaafsma, M., Moxey, A., Martin-Ortega, J., Hanley, N., 2014. A framework for valuing spatially targeted peatland restoration. Ecosyst. Serv 9, 20–33, http://dx.doi.org/10.1016/j.ecoser.2014.02.008.

Gray, A., Levy, P.E., Cooper, M.D.A., Jones, T., Gaiawyn, J., Leeson, S.R., Ward, S.E., Dinsmore, K.J., Drewer, J., Sheppard, L.J., Ostle, N.J., Evans, C.D., Burden, A., Zieliński, P., 2013. Methane indicator values for peatlands: a comparison of species and functional groups. Glob. Chang. Biol. 19, 1141–1150.

Holden, J., Shotbolt, L., Bonn, A., Burt, T.P., Chapman, P.J., Dougill, A.J., Fraser, E.D.G., Hubacek, K., Irvine, B., Kirkby, M.J., Reed, M.S., Prell, C., Stagl, S., Stringer, L.C., Turner, A., Worrall, F., 2007. Environmental change in moorland landscapes. Earth-Sci. Rev. 82, 75–100.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. In: Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds), Agriculture, Forestry and Other Land Use. Prepared by the National Greenhouse Gas Inventories Programme, vol. 4. Institute for Global Environmental Strategies, Hayama, Japan.

IPCC, 2014. 2013 Supplement to the 2006 Guidelines for National Greenhouse Gas Inventories: Wetlands (Wetlands Supplement).

Jensen, R., Landgraf, L., Lenschow, U., Paterak, B., Permien, T., Schiefelbein, U., Sorg, U., Thormann, J., Trepl, M., Wälter, T., Wreesmann, H., Ziebarth, M., 2012. Positionspapier – Potenziale und Ziele zum Moor – und Klimaschutz. Nat. Landsch. 87, 87–88.

JNCC, 2011. Towards an assessment of the state of UK peatlands. Joint Nature Conservation Committee Report No 445.

Joosten, H., 2009. The global peatland CO_2 picture. Peatland status and drainage related emissions in all countries of the world. Wetlands International, Ede.

Joosten, H., 2011. Sensitising global conventions for climate change mitigation by peatlands. In: Tanneberger, F., Wichtmann, W. (Eds.), Carbon Credits from Peatland Rewetting. Climate – Biodiversity – Land Use. Schweizerbart Science publishers, Stuttgart, pp. 90–94.

Joosten, H., Brust, K., Couwenberg, J., Gerner, A., Holsten, B., Permien, T., Schäfer, A., Tanneberger, F., Trepel, M., Wahren, A., 2013a. MoorFutures® Integration von weiteren Ökosystemdienstleistungen einschließlich Biodiversität in Kohlenstoffzertifikate – Standard, Methodologie und Übertragbarkeit in andere Regionen. BfN-Skripten. Federal Agency of Conservation, Bonn.

Joosten, H., Sirin, A., Couwenberg, J., Laine, J., Smith, P., 2013b. The role of peatlands in climate regulation. In: Bonn, A., Allott, T., Evans, M., Joosten, H., Stoneman, R. (Eds.), Peatland Restoration and Ecosystem Services. Cambridge University Press, Cambridge.

Joosten, H., Tapio-Biström, M.-L., Tol, S., 2012. Peatlands – guidance for climate change mitigation by conservation, rehabilitation and sustainable use,

Mitigation of climate change in agriculture series Food and Agriculture Organization of the United Nations. FAO, Rome.
Komulainen, V.-M., Tuittila, E.-S., Vasander, H., Laine, J., 1999. Restoration of drained peatlands in southern Finland: initial effects on vegetation change and CO_2 balance. J. Appl. Ecol. 36, 634–648.
Kosoy, N., Corbera, E., 2010. Payments for ecosystem services as commodity fetishism. Ecol. Econ. 69, 1228–1236.
Kossoy, A., Guigon, P., 2012. State and Trends of the Carbon Market. World Bank Environment Department, Washington D.C.
Lau, W.W.Y., 2013. Beyond carbon: conceptualizing payments for ecosystem services in blue forests on carbon and other marine and coastal ecosystem services. Ocean Coast. Manag. 83, 5–14.
Littlewood, N., Anderson, P., Artz, R., Bragg, O., Lunt, P., Marrs, R., 2010. Peatland biodiversity. Report to IUCN UK Peatland Programme, Edinburgh.
MLUV, 2009. Konzept zum Schutz und zur Nutzung der Moore. Fortschreibung des Konzeptes zur Bestandssicherung und zur Entwicklung der Moore in Mecklenburg-Vorpommern (Moorschutzkonzept). Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz Mecklenburg-Vorpommern, Schwerin.
Moxey, A., 2011. Illustrative economics of peatland restoration. Report to IUCN UK Peatland Programme.
O'Sullivan, R., Emmer, I., 2011. Selling peatland rewetting on the voluntary carbon market. In: Tanneberger, F., Wichtmann, W. (Eds.), Carbon Credits from Peatland Rewetting. Climate – Biodiversity – Land Use, pp. 90–94.
Parish, F., Sirin, A., Charman, D., Joosten, H., Minayeva, T., Silvius, M., Stringer, L., 2008. Assessment on Peatlands, Biodiversity and Climate Change: Main Report. Global Environment Centre, Kuala Lumpur and Wetlands International, Wageningen.
Rabinowitz, R., d'Este-Hoare, J., 2010. The Feasibility of Creating a Funding Mechanism for UK Carbon Reduction Projects, Information Paper.
Reed, M.S., Bonn, A., Evans, C.D., Joosten, H., Bain, C., Farmer, J., Emmer, I., Couwenberg, J., Moxey, A., Artz, R.R.E., Tanneberger, F., Von Unger, M., Smyth, M., Birnie, R., Inman, I., Smith, S., Quick, T., Cowap, C., Prior, S., 2013. Peatland Code research project. Final Report. Defra, London. Available online at: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18642.
Reed, M., Moxey, A., Prager, K., Hanley, N., Skates, J., Bonn, A., Evans, C.D., Glenk, K., Thomson, K., 2014. Improving the link between payments and the provision of ecosystem services in agri-environment schemes in UK peatlands. Ecosyst. Serv. 9, 44–53, http://dx.doi.org/10.1016/j.ecoser.2014.06.008.
Röder, N., Osterburg, B., 2012. The impact of map and data resolution on the determination of the agricultural utilization of organic soils in Germany. J. Environ. Manag. 49, 1150–1162.
Sattler, C., Matzdorf, B., 2013. PES in a nutshell: from definitions and origins to PES in practice – approaches, design process and innovative aspects. Ecosyst. Serv. 6, 2–11.
Tanneberger, F., Wichtmann, W. (eds.), 2011. Carbon credits from peatland rewetting. Schweizerbart Science Publishers, Stuttgart.
van der Wal, R., Bonn, A., Monteith, D., Reed, M., Blackstock, K., Hanley, N., Thompson, D., Evans, M., Alonso, I., Beharry-Borg, N., 2011. Mountains, moorlands and heaths [chapter 5]. In: UK National Ecosystem Assessment. Understanding nature's value to society. Technical Report. Cambridge, UNEP-WCMC, 105–160.
Waddington, J.M., Strack, M., Greenwood, M.J., 2010. Toward restoring the net carbon sink function of degraded peatlands: short-term response in CO_2 exchange to ecosystem-scale restoration. J. Geophys. Res. 115, G01008.
Worrall, F., Chapman, P., Holden, J., Evans, C., Artz, R., Smith, P., Grayson, R., 2011a. A review of current evidence on carbon fluxes and greenhouse gas emissions from UK peatlands. JNCC Research Report 442, Peterborough, p. 45.
Worrall, F., Evans, M.G., 2009. The carbon budget of upland peatland soils. In: Bonn, A., Allott, T., Hubacek, K., Stewart, J. (Eds.), Drivers of Environmental Change in Uplands. Routledge, London and New York, pp. 93–112.
Worrall, F., Evans, M.G., Bonn, A., Reed, M.S., Chapman, D.S., Holden, J., 2009. Can carbon offsetting pay for upland ecological restoration? Sci. Total Environ. 408, 26–36.
Worrall, F., Rowson, J.G., Evans, M.G., Pawson, R., Daniels, S., Bonn, A., 2011b. Carbon fluxes from eroding peatlands – the carbon benefit of revegetation following wildfire. Earth Surf. Process. Landf. 36, 1487–1498.